Subcontracting around research-based spin-off firms as a channel for knowledge distribution

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Subcontracting around research-based spin-off firms as a channel for knowledge distribution*

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In the paper, the specifics of various types of subcontracting linkages around research-based spin-off firms is considered, their dissemination degree in Belarus is assessed, and their economic effects are discussed. The paper shows, that though RSOs' subcontracting relations are organised through price mechanisms, they are surrounded by many non-market interactions, including tacit knowledge and reputation. The paper is based on case studies of research-based spin-off firms in Belarus and Estonia and provides the qualitative empirical evidence on RSOs which can be used both for further in-depth analysis and for the formulation of particular quantitatively provable hypotheses.

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1. Introduction: research-based spin-off firms as an element of the national innovation system

Research-based spin-off firms (RSOs), specialized in R&D and grounded by research institutes, universities, other organisations from science, and their employees, have appeared in Post-Soviet countries in the early nineties. As a new institutional form of the innovation process organisation, RSOs have emerged in response to inability of the linear model to bridge the science and industry. RSOs have undertaken the functions of R&D results transfer and introduction of technological innovations, which have previously been fulfilled by academic and university scientific organisations.

The *higher efficiency* of RSOs in execution of these functions, in comparison with their parental organisations, is explained by:

- application of the non-linear model of the innovation process, including their ability to flexibly react to changes of market requirements with account of customers' feedbacks, and ability to adapt the scientific and technical products to individual requirements of customers.

- smaller costs of development and transfer of technology due to specialization of RSOs in particular technological niches, their lower administration costs and lower transaction costs.

The basis of RSO's *competitive advantage* in comparison with other innovative firms is its ‚key competence' which includes the advanced scientific knowledge; linkages with scientific community and with industry. The functions of RSO's key competence are to provide the knowledge on:

- specifics of development of new products and innovative technologies,
- specifics of partners search and building up of the cooperation linkages,
- strategy of product introduction to the market.

Key competence of the firm can have different degrees of development, which explains the differences in commercial efficiency of particular RSOs beyond their scientific excellence.

2. Problem statement

RSOs source their efficiency in their networks; and it is through these networks that the economic effects from activity of RSOs are spread and disseminated across the national innovation system. In this paper we will concentrate on such type of interactions between RSOs and other actors of the innovation system, as subcontracting.

Subcontracting of R&D services, and services required for R&D performance is an issue of large practical importance, especially of the fact that many aspects need to be considered in subcontracting agreements beyond the final product itself. For example, R&D subcontracts with the former Soviet Union

have become a special subject of USA procurement regulations, where the subcontractor is expected to furnish and deliver the supplies and to perform the services, to provide the necessary equipment, materials, documentation, software, and facilities to fabricate and assemble prototypes, to allow the customer to assess the design and processes for manufacturability, but also to provide the necessary skills for usage of results.

In the paper, we consider the variety of subcontracting linkages around RSOs. We show, that though these subcontracting relations are organised through price mechanisms, they are surrounded by many non-market interactions, including tacit knowledge and reputation naturalization (Pobol, 2005).

3. Theoretical background and research method

In the available Russian-speaking literature on transformation processes in scientific and technical sphere of the postsocialist countries, RSOs are almost not studied. In the world literature, the fragmented empirical research is available, which as a rule covers the applied aspects of firms' functioning. The theoretical studies on principles of RSOs functioning, their interaction with the economic system and their economic effects are generally insufficiently developed; the peculiarities of role of scientific and technical enterprises in the transformation economies are also not considered.

Since J.Schumpeter, I.Kirtzner, R.Coase and O.Williamson, the theory of the innovative firm (Baumol (1968), Alchian and Demsetz (1972), Jensen (1976), Oakey, Rotwell and Cooper (1988), Saxenian (1998), Cooper (1999), Knight (2000), U.Meckling, A.Chandler, F.Scherer, A.Jaffe, U.Lazonik (2005), R.Nelson and S.Winter, J.Hauschild, M.Casson (2005)) is in the process of gradual evolution, sourcing from achievements of narrowly focused empirical works. The theoretical foundations for study of RSOs should thus be supplemented with the neighboring concepts from political economy, economic sociology, neo-institutional economy, economic sociology (Pobol, 2007).

In particular, the concepts of *linear and non-linear innovation process models*, *technological transfer* and *diffusion* by Mansfield (1961) and Klein (1999) play the fundamental role for studying of the innovation process organisation transformations in transitive economies. *Resource-based firm theory* of E. Penrose, the concepts of *specific resources* (Pavitt, 1984) and *local knowledge* (Hayek, 1945) allow to reveal the sources of comparative efficiency and competitive advantage of RSOs. Concepts of general purpose technologies (Carlaw and Lipsey, 2002), transaction costs (Hodgson (1993), Antonelli (2004)), knowledge spillovers (Cohen et al. (2002), Carlaw and Lipsey (2002)) and network innovation structures (Granovetter (1973), Callon and Law (1986), Powell (2005)) can be used as analytical tools for disclosing

of economic essence of effects around RSOs. Conceptual foundations of policy in relation to RSOs rest on the concepts of *path dependence, innovation culture, national innovation systems* (Lundvall et al., 2002).

The leading works on drawing the theory of research-based spin-offs in the world belong to Autio (1997), Granstrand (1998), Chesbrough (2003), Mustar et al. (2008). Complementary empirical research on RSOs in Post-Soviet countries can be found by Akhmetova (2005), Dezhina and Saltykov (2005). Our research (Pobol, 2009) has generalized the vast empirical evidence in order to disclose the regularities of functioning of research-based spin-off entrepreneurship as an element of the national innovation system, which resulted in development of a theoretical concept of scientific and technical spin-off entrepreneurship, including its goals, contents, forms of existence and development, economic relations, their conflicts and contradictions, functions and effects in the national innovation system, and drawing a block of measures for improvement of the innovation policy concerning RSOs.

Subcontracting relations are involved into discussion in some recent RSO-literature. For instance, van Liemt (2007) shows on example of electronics in Denmark how the former subcontracting companies turn into providers of services themselves.

Different papers demonstrate the significance of the proper organisational form and business model of interaction with other economic actors for success of the research-based spin-off enterprise. E.g., Ndonzuau, Pirnay and Surlemont (2002) have developed a stage model of the global academic spin-off creation process, where institutional and personal relationships with the university of origin affect the stage of launching of spin-off firms, and the choice of a proper trajectory of the market service can strengthen the creation of economic value. Garnsey, Lorenzoni and Ferriani (2008) consider the techno-organisational changes which were needed to launch a dominant technical standard, compatible with multiple applications. One of their most important conclusions have been that the inherited knowledge together with organisationally based learning foster the branching and renewal of technological lineages, or, in the other words, the speed of technological progress positively depends on managerial knowledge and ability to learn, not only on technological knowledge itself.

The other papers demonstrate, which most important types of resources are needed to run a successful RSO. So, Souitaris, Morray, Clarysse, Zerbinati (2006) compare the mean capital in the first year for different incubation models and for different technology domains, showing that the size of capital to start-up a spin-off firm is a key factor to their growth. And Müller (2008) studies the time to collect competences for spin-off establishment and shows that a longer time-lag is caused by the necessity of assembling complementary skills, either by acquisition by a single founder or by searching for suitable

team members. Her other findings are that new ventures are established earlier if the intensity of technology transfer is high, the founders have access to university infrastructure, or received informal support by former colleagues; the time-lag of spin-off establishments in teams is shorter than the time-lag of single founders: and certain combinations of academic subjects have a positive effect on transfer speed. Finally, Conceição, Fontes, Calapez (2009) analyse the factors of spin-offs commercialisation strategies' choices to sell or license the technology versus to embody the technology into products or services, like the nature of knowledge being exploited, knowledge appropriability conditions, location and degree of control upon critical non- technological assets, and source institutional setting.

With account of lack of literature to our specific research question and lack of disaggregated statistics on RSOs, the methodological approach of this paper leans on independent empirical study of RSOs with opportunistic data collection. There have been conducted 10 case studies with RSOs in Belarus, Estonia and France, supplemented by over 20 interviews with administration of innovative infrastructure organisations, directors and experts from scientific organisations, who possess the practical experience of work with RSOs. Additional tools of data collection have been the co-organisation by author of technology transfer events, and visits to RSOs' manufacturing areas.

4. RSO's subcontracting linkages and their knowledge content

RSOs enter the relations of subcontracting at various stages of the innovation process, where they can be both customers and executors. We consider these relations by type of counterpartner.

4.1. Industrial enterprises.

Industrial enterprises are the most common type of RSOs' customers. Transfer of innovative equipment and technologies to them are escorted by the market (via price mechanisms) and non-market knowledge flows (knowledge spillovers).

The market knowledge flows occur through teaching of workers of the enterprises-customers within the agreed period after introduction of technology and equipment, and these services may be included into the price of final product. RSOs maintain close contact to the customer at a stage of equipment introduction and in the first year of its operation, train, advise and correct the possible defects of the innovative equipment revealed during operation (Smallbone et al. 2008) (the concept «learning-by-using» of N. Rosenberg (1982)).

The non-market knowledge flows are the complementary knowledge flows which escort the

"relevant" technological knowledge but are not agreed upon in the contract. For instance, these are the knowledge about possibilities and restrictions of alternative applications of the innovative technologies and equipment, about other – complementary or partially substituting – technologies, other – probably competitive – enterprises which have also introduced this technology, etc.).

The basis for knowledge spillovers is the need of tight communication between customers and researchers for the sake of finding a concrete solution for their specific need (technologies and equipment suggested by RSOs are tuned up for specific profile of customer's demand). Frequently cooperation between the customer and the executor develops beyond the administrative and coordinating actions towards direct participation of the customer in the order execution. For example, industrial enterprises direct their own workers to performance of necessary works (as manufacture of details and assemblage of the ordered equipment), which serves the purpose of reduction of their expenses in the monetary form (Pobol, 2005). Most successful is the cooperation with those customers who possess the high technological competence that provides 1) the quality of formulation of the customer's problem; 2) the quality of feedback from customer about problem solutions offered by researchers; 3) full value of use by customers of results in practice (this empirical evidence confirms the applicability of the diffusion theory in the transformation economy of Belarus).

Also the other reverse knowledge spillovers can take place, when in the process of customers' technical support RSOs get access to internal information of customers about the economic gains derived by them from usage of technological knowledge received from the RSO. This knowledge can help RSOs to develop their pricing strategy.

4.2. Parent scientific organisations.

RSO's customers may include their parent scientific organisations, for example for rapid fulfillment of state tasks on product development within limited budget and tight deadlines. Often scientific research institutes subcontract to their spin-offs the execution of some R&D in the framework of large state scientific and technical programs. Cooperation of RSOs with parent scientific organisations is mutually beneficial (economically efficient), because they act at the sequential links of the innovation process. Flexibility in adjustment to market needs, quickness of order execution and the relative cheapness of RSOs' science-intensive products, combined with the guarantee of their parent organisations' quality, positively influence the industrial customers' decisions to participate in joint projects with state scientific organisations. Cooperation of RSOs and their parent scientific organisations "saves institutes from standby time that negatively influences scientific groups…. gives possibility of self-

realisation to scientists in the large institutes where the hierarchy is severe" (Dmitriev, 2003). Schemes of RSOs' relations with parent organisations vary by countries. The choice of organisational forms for R&D results commercialization depends on various factors (table 1) and can influence the success of technologies' commercialization on the early stages of RSOs' life cycle.

Parent universities and scientific research institutes pass to RSOs which have spun-off from them the right to rent both office and (sometimes specific) manufacturing areas and infrastructure, and, what is most important, the equipment (installations, devices) which can be unique in the territory of the country or excessively expensive for a young small enterprise.

A special kind of „good" transferred during collaboration between RSO and its parent organisation, as well as RSOs of the first and second generation and firms working in the same technological area, is the *scientific reputation*. The reputation (trademark) of the scientific and technical enterprise is a public perception of the quality and amount of competence (knowledge) put in a product or process. E.g., a large share of RSOs have spun-off in Belarus from the Physical-Technical Institute of the National Academy of Sciences ("Phystech", or "FTI"), which is renown for developing innovative technologies since already over 70 years. Even competitors recognize that ""Phystech" is a trademark of the world value". The fact that a particular RSO has branched off from FTI, almost automatically means for customers a high quality of technologies suggested by this RSO, confirmed with decades of cooperation of industrial enterprises of Belarus, Russia, Ukraine and other Post-Soviet countries with the FTI. Similarly, origin from the oldest universities can play a role of a "visit card" for RSOs that search expanding their markets in the EU territory (as it is observed in Estonia). Second generation RSOs also can raise their reputation in the market by emphasizing in their marketing strategy of their linkages to the "school of founders" of particular technological direction.

After establishment of an independent research-based enterprise, the relations of RSOs and scientific organisations can develop under various schemes. A major factor which determines the degree of narrowness of cooperation between RSO and scientific research institute or high school, is a distance between stages of their R&D. Therefore cooperation of RSOs with universities where R&D are far from stage of ready to the market products, are seldom; cooperation of RSOs with applied scientific research institute is more probable.

4.3. Second generation spin-offs.

Knowledge flows occur through migration of employees from the first generation RSOs to the second generation RSOs. These people are the carriers of the *key technological knowledge* which has arisen in the first generation RSO's parental organisation, but also carriers of knowledge of a *way of development of the basic technology in reply to specific market requirements*, and about the *directions, which turned out unsuccessful*. Finally, the second generation RSO may receive the *contacts to suppliers and clients in the given technological sphere* and knowledge of *effective schemes of interaction with these suppliers and customers*.

RSOs can also interact with "sister firms" (stemming from the same parent organisations, and thus, sharing the common knowledge background), and "stepbrothers" (stemming from different organisations, but working in the same technological area), sharing knowledge both informally and through contract relations.

4.4. Other scientific and technical firms.

Other scientific and technical firms, which need the innovative products of RSOs for development of their own innovative technologies, equipment and products, are among the most advanced customers of RSOs, possessing the most complex technological competence. It is the interaction with these actors that drives the continuous improvement of R&D level of RSO in the forefront of the demand of more traditional industrial enterprises that only absorb innovations, but do not create them themselves. The growing importance of this interaction is supported by the world tendencies of the growing R&D specialization and interconnection between high-tech technological fields.

In Belarus, RSOs constantly co-operate with the former colleagues from parent scientific research institutes, which maintains their knowledge update about R&D achievements of the academic science and experts in the specialised technological areas. Often RSOs are the members of specialised scientific organisations and associations; they frequently participate at the international conferences.

Since the combination of knowledge from various technological fields is often needed for new solutions, the experts of other enterprises and research organisations are regularly involved in performance of separate specific works by subcontracting (for example, experts in thermal processing, in design, working out of the special equipment). Specific structures of cooperation are formed for «brain storming» - temporary scientific teams with experts from the various organisations for finding of an interdisciplinary solution.

Through subcontracting, RSOs can themselves be customers of scientific and technical firms, whose results of R&D are used for advancement of innovative technologies and products of RSOs; suppliers of raw materials, materials, components, nodes, etc.

RSOs can also be donors of resources themselves. There are cases observed when the innovators assist each other in technological cooperation informally, for example, by allowing the another RSOs to conduct tests at unique or rare installations, and even carrying out tests for them. Sometimes privately-owned RSOs that have achieved commercial success, pass the installations created by them for their own technological process, to enterprises or the factories making the similar products both in Belarus, and in Russia. «These firms are not competitors to us now, they possess no real experts, they are practically bankrupts, and the equipment which we have developed, is passed to them on the basis of cooperation, otherwise they would die» (from interview with a respondent). The donation of RSO's resources to enterprises operating in the similar technological area, is not dangerous for RSOs if the recepients possess only the ability to adapt the innovative technologies in manufacture, but not the innovation capability. The purposes can be support of friends; preservation of partners-innovators in the region; "heating" of the market.

Factors which aspire the innovators to interact with players with the similar competence, who are the potential competitors, include:

– corporate culture of the scientists, shared norms and values of the innovative organisation (de Brentani, 2004). The founders of innovative firms, who belong to leading scientists, elite of the country's scientific community, identify themselves primarily with scientific, and only next with the business sphere;

– high interdependence of technologies in the high-tech sphere;

– aspiration to lower the transaction costs of R&D results transfer between various areas.

Network cooperation of scientific and technical enterprises allows to collect the critical mass of specialized resources and to provide their more effective distribution for creation of an innovative product. The advantages of cooperation include:

– the combination of advantages of large firms (the smoothly running management of financial flows and accounting reporting) and small firms (flexibility, smaller bias in research, avoidance of resources scattering);

– overcoming of weaknesses of concrete enterprises and fuller use of potential of each firm;

– possibility of attraction of the customer with the large-scale project;

– sharing of risks and expenses;

– internal effect of self-training of a network.

A necessary condition for formation of a network is the availability of solvent demand for its products. The restricting factors for networking include:

– need in a certain combination of competences of firms for realisation of the joint project, which might not be available in the national innovation system simultaneously due to narrow specialisation of scientific and technical enterprises;

– ease of emergence of the conflict of interests when public funds and the private capital are simultaneously involved in the project (confrontation of long-term purposes and purposes of immediate return on the invested capital);

– necessity of overcoming of technological isolation at the initial stage of development of the young enterprise;

– necessity of development of certain degree of trust.

Interaction with a large high-tech company can become a source of the rarest resources for a young enterprise: capital for launching of the large-scale science-intensive manufacture, and international management experience. The basic schemes of interaction include a the subcontracting network, direct foreign investments, acquisition. Benefits for RSO from interaction with a large high-tech company, besides financial investments, include:

- access to new technologies and rare equipment;
- access to non-codified technological knowledge and training;
- possibility of adaptation of the experts preparation system to the world labour market;
- possibility of acquisition of skills of the international business dialogue and decision-making abroad. These positive internalities can become an equally important asset for a young RSO, as the initial capital accumulation.

Due to growing complexity of the innovative technologies and products, the scheme of bringing of a small scientific and technical firm to its absorption by the large one is often used. In the countries with well financed scientific base researchers create small enterprises for completion of innovative technology or a product, check their exploitability for the market, establish contacts to the basic consumers in the world, thus forming the high market value of the firm, and then sell it to large corporations which undertake marketing costs and costs of product mastering by consumers.

4.5. Foreign investors.

Foreign investors or firms which organise manufacture in the territory of the domestic country and need suppliers of science-intensive products and services, prefer R&D collaboration with RSOs rather

than with universities or state scientific institutes, mainly due to avoidance of contradictions of goals (short-term orientation of enterprises on solution of concrete practical problems, and long-term cognitive goals of fundamental research organisations), and conflicts of interests caused by difference of ownership forms (private versus public).

Until recently many RSOs managers have considered the option of foreign direct investments attraction to be a single opportunity of development for a firm since it provided tax privileges and the more loyal attitude of controlling bodies. Now foreign investments are the major source of large investments since the venture capital is rare in Belarus.

The conflicts of interests concerning distribution of intellectual property rights on the R&D results can also emerge between RSOs and other enterprises in collaborative R&D, especially when their inputs into the cooperative R&D process have had the various substances (financial, human resources or equipment). Because the value of knowledge is difficult to measure, often the final distribution is biased towards a player with larger capacities and power (e.g. multinational corporations), irrespective of their actual inputs. Therefore, the mutually beneficial collaboration is more likely to emerge between the firms of approximately equal size.

Non-marketed knowledge flows escort the contracts between RSOs and foreign enterprises, like “local” knowledge, e.g. on technological specifics of local production and access to local networks in scientific and industrial communities. Simultaneously, if a foreign enterprise is a customer, a secondary economic effect can emerge of RSO’s integration into the world economy and its training to carry out activity on the world market. One example of this is a Belarusian enterprise which launches a joint venture in China in order to get integrated beforehand into the structure of market of the country which will become a leader in their technological field in the future (Smallbone et al., 2008).

4.6. State.

Subcontracts from the state (order on technological innovations) in certain strategic directions of technological development can play a significant role in RSOs development especially on the early stage of the it’s lifecycle, when the young firm is not known to market yet and has few orders, but the wages to employees need to be paid. By stimulating the development of a certain growth trajectory of the RSO, the state order can minimize the risks that the RSO will have to divert resources to low-value added technological solutions and will therefore loose its competitive advantage to the good of other countries. In practice, strategic alliances of Belarusian RSOs and government are yet seldom due to over-complicated bureaucratic formal procedures and danger for private enterprises of becoming an object of

exaggerated attention of inspection bodies.

The type of RSOs' cooperative linkages with other actors changes in time due to evolution of the national innovation system, maturing of the innovative technology and learning of the RSO.

5. Conclusions: effects from RSO's subcontracting linkages

Economic effects from activity of RSO in NIS can be identified which cannot be completely internalised by firm but influence the other economic actors. The main channels of distribution of these effects are the networks of interaction of RSO with NIS. The mechanism of some effects from the process of subcontracting of jobs and services by research-based spin-offs is somewhat similar to those of the Keynesian multiplier-accelerator: include the expansion of firms which have received an order; creation of additional employment; demand-driven product modifications; process improvements by means of learning-by-doing and learning by access to tacit knowledge of customers. Positive effects include the diffusion of innovations; intensification of cooperation of science and industry; reduction of transaction costs of the innovative cooperation; technological modernisation; improvement of technological structure of economy; improvement of structure of international trade and integration of NIS into the world technological system; attraction of foreign investments into the high technology manufactures; development of innovation culture.

Generally, emergence and development of RSO is a part of the world transformation process in the scientific and technical sphere that is caused by the growing complexity of technologies and globalisation processes. It transforms the scientific and technical sphere into the national innovation system in two ways: through the appearance in the economy of private source of financing of scientific and technological progress; and through transition from linear model of the innovation process to the more efficient nonlinear model based on feedback from demand.

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Table 1. Main reasons for choice by scientists of the organisational forms of R&D results realization

Type of factors	Organisational forms of R&D results realisation		
	Innovative activity in the framework of parent organisation without grounding of a new firm	**Grounding of a new firm with preservation of tight linkages with the parent organisation**	**Grounding of a new firm without linkages with the parent organisation**
Objective factors	The scale of R&D works, expensive research equipment, the necessary starting capital is too large	Spatial affinity to university: colleagues, students, infrastructure	Absence of need in the specific infrastructure
Environment-specific factors	Access to additional sources of R&D funding on more favorable conditions - is especially actual for young technologies which require completion before exit to the market; at a stage of the poorly developed demand; in conditions of rarity of customers financing R&D	Possibility to rent office premises and manufacturing spaces or to combine the usage of research infrastructure both for academic, and for the research purposes under prices below market level and with smaller transaction costs	Situation when the possible benefits from using services of the parent organisation are less, than costs from the moral and legal restrictions imposed by maintenance of communications with it
Resource factors	Success of researchers in international projects applications, causing satisfaction with the wage level and loss of monetary incentive to start-up of the own firm	Possibility to share the book keeping, cleaning and guarding of premises, the information and communication infrastructure with the parental organisation	
Reputation factors	For success in gaining funds for R&D, the parent organisation with the world reputation needs to perform as the leading institution.	The database of international contacts accumulated by parent scientific research institute or high school; their "trademark" in the international market	Absence of positive externalities from usage of parent organisation's trademark
Psyhological factors	The collective character of R&D, which potentially might cause the reproaches in knowledge theft in the narrow circle of experts	Friendly relations with the management of parent scientific research institutes and high schools, institutional support rendered by them	Unfriendly relations with the management of parent organisations

Source: Pobol and Kalvet (2006).